

## **CONSTANT VELOCITY BALL JOINT AS A COUNTER TRACK JOINT**

### **Technical Field**

[0001] The present invention relates to a constant velocity ball joint permitting axial displacement.

### **Background Of The Invention**

[0002] The most frequent type of plunging joints are so-called VL joints (cross-groove joints) such as according to DE 31 02 871 C2 wherein the center lines of the outer tracks and of the inner tracks each form oppositely directed angles of intersection with the longitudinal joint axis and are positioned in planes extending parallel to the longitudinal joint axis or on a cylindrical face around the longitudinal joint axis.

[0003] From U.S. Patent No. 3,133,431, there are known plunging joints wherein the center lines of the outer tracks and of the inner tracks form identically sized angles of intersection with the longitudinal joint axis, i.e., they are positioned in planes which contain the longitudinal joint axis itself.

[0004] Both the above-mentioned types of joint are joints with straight tracks.

[0005] It would be desirable to provide a new type of plunging joint for large articulation angles and relatively short displacement paths.

### **Summary Of The Invention**

[0006] The present invention provides a constant velocity ball joint in the form of a counter track joint. The joint includes an outer joint part with outer tracks, an inner joint part with inner tracks, torque transmitting balls which are received in pairs of tracks consisting of outer tracks and inner tracks which are curved outwardly with reference to the longitudinal joint axis A, and a ball cage with cage windows in which the balls are held in a common plane and are guided on to the angle-bisecting plane when the joint is articulated. First outer tracks, together with first inner tracks, form first pairs of tracks whose first control angles  $\beta_1$  open in a first axial direction and in which first balls are held. Second outer tracks, together with second inner tracks, form second pairs of tracks whose second control angles  $\beta_2$  open in a second axial direction and in which second balls are held. The control angles  $\beta_1$ ,  $\beta_2$  are defined as angles between tangential planes at the ball contact points in the tracks. Further, the outer joint part and the inner joint part are axially displaceable relative to one another and the first control angles  $\beta_1$  and the second control angles  $\beta_2$  change in opposite senses when a relative axial displacement occurs. The axial displacement path  $V_{\max}$  is limited to a maximum value that produces a minimum value of at least  $8^\circ$  for the respective smaller control angles  $\beta_1$ ,  $\beta_2$ . The present joint provides an axial displacement path having at least 0.8 mm, and preferably more than 1.0 mm of play. This is substantially above the axial play of fixed joints, which in comparison is at most 0.5 mm.

[0007] In one form of the displacement path, the joint in accordance with the invention provides a way to uncouple axial vibrations and thus contributes towards improving the noise, vibration, harshness (NVH) behavior. The present design is also advantageous in that it is possible to un-fine the surfaces during the machining operations. Also, the design of the tracks provides a joint with axial centring characteristics.

[0008] In particular, the tracks are curved as in Rzeppa joints or undercut-free (UF) joints. As a consequence, even with larger articulation angles, there is achieved adequate ball control due to sufficiently large control angles.

[0009] By limiting the axial displacement path, it is ensured that the control angles do not become too small as a result of the axial displacement. The stops for delimiting the axial plunging path can become effective exclusively between the outer joint part and the cage, or exclusively between the inner joint part and the cage, or between both pairs simultaneously; in each case when the joint is in the aligned position, in which case the longitudinal axes of the inner joint part and of the outer joint part coincide. As the ball cage is radially set free relative to the inner joint part and to the outer joint part, the joint is characterised by particularly low friction. Furthermore, because of the counter-track formation, it is ensured that the joint is axially self-centring and that the forces acting on the cage are kept within certain limits. In addition, the way in which the balls are enveloped by the tracks in a cross-sectional view is particularly advantageous.

[0010] Other advantages of the invention will become apparent upon reading the following detailed description and appended claims, and upon reference to the accompanying drawings.

### **Brief Description Of The Drawings**

[0011] For a more complete understanding of this invention, reference should now be made to the embodiments illustrated in greater detail in the accompanying drawings and described below by way of examples of the invention.

[0012] In the drawings, fixed joints with counter tracks are compared with inventive joints; both will be described in detail below.

[0013] Figure 1 shows a prior art fixed joint with counter tracks according to the state of the art, having Rzeppa tracks: (a) in a longitudinal section through a pair of counter tracks; (b) in a bent longitudinal section through a cage web.

[0014] Figure 2 shows a prior art fixed joint with counter tracks, having undercut-free (UF) tracks: (a) in a longitudinal section through a pair of counter tracks; (b) in a bent longitudinal section through a cage web.

[0015] Figure 3 shows an inventive joint in a first embodiment with Rzeppa tracks in a bent longitudinal section through a cage web.

[0016] Figure 4 shows a detail X of Figure 3 in an enlarged scale: (a) in an axially centered position of the joint; (b) with maximum axial displacement of the joint.

[0017] Figure 5 shows an enlarged detail of a joint similar to that illustrated in Figure 3 with maximum axial displacement: (a) in a first modified embodiment; (b) in a second modified embodiment.

[0018] Figure 6 shows an inventive joint in a second embodiment with Rzeppa tracks in a bent longitudinal section through a cage web.

[0019] Figure 7 shows a detail X of Figure 6 in an enlarged illustration: (a) in an axially centered position of the joint; (b) with maximum axial displacement of the joint.

[0020] Figure 8 shows an inventive joint in a third embodiment with Rzeppa tracks in a bent longitudinal section through a cage web.

[0021] Figure 9 shows the detail X of Figure 8 in an enlarged scale: (a) in an axially centered position of the joint; (b) with a maximum axial displacement of the joint.

[0022] Figure 10 shows an inventive joint in a fourth embodiment with Rzeppa tracks in a bent section through a cage web.

[0023] Figure 11 shows the detail X of Figure 10 in an enlarged scale: (a) in an axially centered position of the joint; (b) with maximum axial displacement of the joint.

[0024] Figure 12 illustrates the principle of an inventive joint in a longitudinal section through a pair of counter tracks, leaving out the ball cage: (a) with maximum axial displacement in a first direction; (b) in an axially centered position of the joint; (c) with maximum axial displacement in the second direction.

### Detailed Description Of The Invention

[0025] Figures 1 and 2 refer to prior art joints for comparative purposes and to complete the description. They will be described jointly. A joint 11 includes an outer joint part 12 with a formed-on journal 13, an inner joint part 14 with a plug-in aperture 15 for a shaft, balls 16<sub>1</sub>, 16<sub>2</sub> and a cage 17 having windows 18 in which the balls are held. The joints are counter track joints. Thus, first outer ball tracks 19<sub>1</sub> in the outer joint part 12 and first inner ball tracks 20<sub>1</sub> in the inner joint part 14, which tracks hold first balls 16<sub>1</sub>, are designed axially oppositely relative to second outer ball tracks 19<sub>2</sub> in the outer joint part 12 and second inner ball tracks 20<sub>2</sub> in the inner joint part 14, which tracks hold second balls 16<sub>2</sub>. The first pairs of tracks 19<sub>1</sub>, 20<sub>1</sub> have control angles which open in a first direction R<sub>1</sub>. The second pairs of tracks 19<sub>2</sub>, 20<sub>2</sub> have control angles which open in a second direction R<sub>2</sub>. The counter track formations are achieved in that the centers of curvature of the outer ball tracks 19<sub>1</sub>, 19<sub>2</sub> in the outer joint part are circumferentially alternately offset in opposite axial directions relative to the central joint plane E, and equally, the centers of curvature of the inner ball tracks 20<sub>1</sub>, 20<sub>2</sub> in the inner joint part 14 are circumferentially alternately offset in opposite axial directions relative to the central joint plane E. The central joint plane is defined by the centers of the balls.

[0026] The ball cage 17 includes a spherical outer face 21 which is guided in a spherical inner face 22 of the outer joint part 12. Furthermore, the cage includes a spherical inner face 23 in which there is guided a spherical outer face 24 of the inner joint part 14. As a result of this configuration, the joints become fixed joints.

[0027] The track center lines  $9_1$ ,  $10_1$  of the tracks  $19_1$ ,  $20_1$  as well as the track center lines  $9_2$ ,  $10_2$  of the tracks  $19_2$ ,  $20_2$  intersect one another in the central joint plane E when the joint is in the aligned condition. Whereas in Figure 1, the center lines 9, 10 of the tracks are entirely circular arches, the center lines 9, 10 of the tracks in Figure 2 are formed by circular arches with an adjoining axis-parallel tangent.

[0028] Figure 3 shows a joint  $11_3$  which is similar to that shown in Figure 1 but differs substantially in certain details. The details which correspond to one another have been given the same reference numbers. To that extent, reference is made to the description above. In particular, reference is made to the illustrated outer tracks  $19_1$  and inner tracks  $20_1$  as well as to the outer tracks  $20_2$  and inner tracks  $20_2$  which are not shown in Figure 3 for simplification. The details which deviate from Figure 1 have been given the index 3 and will be referred to below. With the joint of Figure 3, the spherical outer face  $21_3$  of the ball cage  $17_3$  is arranged at a radial distance from the spherical inner face  $22_3$  of the outer joint part  $12_3$ . Furthermore, the spherical inner face  $23_3$  of the ball cage  $17_3$  is arranged at a radial distance from the spherical outer face  $24_3$  of the inner joint part  $14_3$ . As a result, there is achieved, as will be explained in greater detail below, a relative axial displaceability between the outer joint part  $12_3$  and the inner joint part  $14_3$ , with the ball cage  $17_3$  setting itself to half the path.

[0029] In Figure 4a, in the enlarged detail X of Figure 3, any details corresponding to those in Figure 3 have been given the same reference numbers, with reference being made to the previous description.

[0030] In Figure 4b, the enlarged detail X of Figure 3 is in a modified position, with the central joint plane, in its relative position relative to the outer joint part 12<sub>3</sub>, being arbitrarily used as the reference plane E<sub>B</sub>. With respect hereto, the inner joint part 14<sub>3</sub> is axially moved towards the right by the displacement path VI, whereas the ball cage 17<sub>3</sub> is moved towards the right by half the size of the displacement path VC. In this position, an inner edge 25<sub>3</sub> of the outer joint part 12<sub>3</sub> stops against the outer face 21<sub>3</sub> of the ball cage 17<sub>3</sub>, whereas at the same time an outer edge 26<sub>3</sub> of the inner joint part 14<sub>3</sub> stops against the inner face 23<sub>3</sub> of the ball cage 17<sub>3</sub>. An outer edge 27<sub>3</sub> of the ball cage and a second outer edge 28<sub>3</sub> of the inner joint part form corresponding stops, with the displacement path of the same size extending in the opposite direction. An angle  $\alpha_1$  at the ball cage is the angle between the central plane of the ball cage and the line of contact with the edge 25<sub>3</sub>, and an angle  $\alpha_2$  at the ball cage 17<sub>3</sub> is the angle between the central plane of the ball cage and the line of contact with the edge 26<sub>3</sub>. The radius of the inner face 22<sub>3</sub> at the outer joint part has been given the reference symbol RO and the radius of the face 21<sub>3</sub> at the ball cage has been given the reference symbol RC.

[0031] Figure 5a shows part of a modified inventive joint similar to that illustrated in Figure 4b. Identical parts have been given identical reference numbers, but are identified by the index 4. As a result of modified radii, only one circumferential edge 26<sub>4</sub> of the inner joint part 14<sub>4</sub> touches the inner face 23<sub>4</sub> of the ball cage 17<sub>4</sub>, whereas in this axial stopping position, the outer face 21<sub>4</sub> of the ball cage 17<sub>4</sub> still has radial play relative to the inner edge 25<sub>4</sub> of the outer joint part 12<sub>4</sub>. A second outer edge 28<sub>4</sub> of the inner joint part forms a corresponding stop, with the displacement path of the same size extending in the opposite direction. An angle  $\alpha$  at the ball



cage 17<sub>4</sub> is the angle between the displaced central plane and a radius through the contacting edge.

[0032] Figure 5b shows part of a modified inventive joint similar to that illustrated in Figure 4b. Identical parts have been given identical reference numbers, but are identified by the index 5. As a result of modified radii, only one circumferential edge 25<sub>5</sub> of the outer joint part 12<sub>5</sub> touches the outer face 21<sub>5</sub> of the ball cage 17<sub>5</sub>, whereas in this axial stopping position, the inner face 23<sub>5</sub> of the ball cage 17<sub>5</sub> still has radial play relative to the outer face 23<sub>5</sub> of the inner joint part 14<sub>5</sub>. An outer edge 27<sub>5</sub> of the ball cage forms a corresponding stop, with the displacement path of the same size extending in the opposite direction. An angle  $\alpha$  at the ball cage 17<sub>5</sub> is the angle between the displaced central plane and a radius through the contacting edge.

[0033] Figure 6 shows a joint 11<sub>6</sub> which is similar to that shown in Figure 1 but differs substantially in certain details. The details which correspond to one another have been given the same reference numbers. To that extent, reference is made to the description above. In particular, reference is made to the illustrated outer tracks 19<sub>1</sub> and inner tracks 20<sub>1</sub> as well as to the outer tracks 19<sub>2</sub> and inner tracks 20<sub>2</sub> which are not shown in Figure 6, for simplification. The details which deviate from Figure 1 have been given the index 6 and will be referred to below. With the joint of Figure 6, the spherical outer face 21<sub>6</sub> of the ball cage 17<sub>6</sub> is radially centered in an internally cylindrical inner face 22<sub>6</sub> of the outer joint part 12<sub>6</sub>, but has axial play relative to two adjoining internally conical stop faces 29<sub>6</sub>, 30<sub>6</sub>. Furthermore, the inner face 23<sub>6</sub> of the ball cage 17<sub>6</sub> is arranged at a radial distance from the spherical outer face 24<sub>6</sub> of the inner joint part 14<sub>6</sub>. As a

result, there is achieved, as will be explained in greater detail below, a relative axial displaceability between the outer joint part 12<sub>6</sub> and the inner joint part 14<sub>6</sub>, with the ball cage 17<sub>6</sub> setting itself to half the displacement path.

[0034] In Figure 7a, in the enlarged detail X of Figure 6, the same details as in Figure 6 have been given the same reference numbers, with reference being made to the previous description.

[0035] In Figure 7b, the enlarged detail X of Figure 6 is in a modified position, with the central joint plane, in its relative position relative to the outer joint part 12<sub>6</sub>, being arbitrarily used as the reference plane E<sub>B</sub>. With reference hereto, the inner joint part 14<sub>6</sub> is axially moved towards the right by the displacement path VI, whereas the ball cage 17<sub>6</sub> is moved towards the right by half the size of the displacement path VC. In this position, an inner edge 25<sub>6</sub> of the outer joint part 12<sub>6</sub> stops against the outer face 21<sub>6</sub> of the ball cage 17<sub>6</sub>, whereas at the same time an outer edge 26<sub>6</sub> of the inner joint part 14<sub>6</sub> stops against the inner face 23<sub>6</sub> of the ball cage 17<sub>6</sub>. An outer edge 27<sub>6</sub> of the ball cage and a second outer edge 28<sub>6</sub> of the inner joint part form corresponding stops, with the displacement path of the same size extending in the opposite direction. An angle  $\alpha$  at the ball cage 17<sub>6</sub> is the angle between the central plane of the ball cage and the line of contact with the edge 25<sub>6</sub>. The radius of the face 21<sub>6</sub> at the ball cage has been given the reference symbol RC.

[0036] Figure 8 shows a joint 11<sub>8</sub> which is similar to that shown in Figure 1, but differs substantially in certain details. The details which correspond to one another have been given the same reference numbers.

To that extent, reference is made to the description above. In particular, reference is made to the illustrated outer tracks 19<sub>1</sub> and inner tracks 20<sub>1</sub> as well as to the outer tracks 19<sub>2</sub> and inner tracks 20<sub>2</sub> which are not shown in Figure 8, for simplification. The details which deviate from Figure 1 have been given the index 8 and will be referred to below. With the joint of Figure 8, the spherical outer face 21<sub>8</sub> of the ball cage 17<sub>8</sub> is radially centered in the spherical inner face 22<sub>8</sub> of the outer joint part 12<sub>8</sub>. Furthermore, the inner face 23<sub>8</sub> of the ball cage 17<sub>8</sub> is arranged at a radial distance from the spherical outer face 24<sub>8</sub> of the inner joint part 14<sub>8</sub>. As a result, there is achieved, as will be explained in greater detail below, a relative axial displaceability between the outer joint part 12<sub>8</sub> and the inner joint part 14<sub>8</sub>, with the ball cage 17<sub>8</sub> setting itself to half the displacement path.

[0037] In Figure 9a, in the enlarged detail X of Figure 8, the same details as in Figure 8 have been given the same reference numbers, with reference being made to the previous description.

[0038] In Figure 9b, the enlarged detail X of Figure 8 is in a modified position, with the central joint plane, in its relative position relative to the outer joint part 12<sub>8</sub>, being arbitrarily used as the reference plane E<sub>B</sub>. With reference hereto, the inner joint part 14<sub>8</sub> is axially moved towards the right by the displacement path VI, whereas the ball cage 17<sub>8</sub> is moved towards the right by half the size of the displacement path VC. In this position, an outer edge 26<sub>8</sub> of the inner joint part 12<sub>8</sub> stops against the inner face 23<sub>8</sub> of the ball cage 17<sub>8</sub>. A second outer edge 28<sub>8</sub> of the inner joint part forms a corresponding stop, with the displacement path of the same size extending in the opposite direction. An angle  $\alpha$  at the ball cage 17<sub>8</sub> is the angle between the central plane of the ball cage and the line of contact with the

edge 26<sub>s</sub>. The radius of the outer face 24<sub>s</sub> at the inner joint part has been given the reference symbol RI and the radius at the inner face 21<sub>s</sub> at the ball cage has been given the reference symbol RC.

[0039] Figure 10 shows a joint 11<sub>10</sub> which is similar to that shown in Figure 1, but differs substantially in certain details. The details which correspond to one another have been given the same reference numbers. To that extent, reference is made to the description above. In particular, reference is made to the illustrated outer tracks 19<sub>1</sub> and inner tracks 20<sub>1</sub> as well as to the outer tracks 19<sub>2</sub> and inner tracks 20<sub>2</sub> which are not shown in Figure 10, for simplification. The details which deviate from Figure 1 have been given the index 10 and will be referred to below. With the joint of Figure 10, the spherical outer face 21<sub>10</sub> of the ball cage 17<sub>10</sub> is radially centered in an internally cylindrical inner face 22<sub>10</sub> of the outer joint part 12<sub>10</sub>. Furthermore, the spherical outer face 24<sub>10</sub> of the inner joint part 14<sub>10</sub> is centered in the internally cylindrical inner face 23<sub>10</sub> of the ball cage 17<sub>10</sub>. As a result, there is achieved, as will be explained in greater detail below, a relative axial displaceability between the outer joint part 12<sub>10</sub> and the inner joint part 14<sub>10</sub>, with the ball cage 17<sub>10</sub> setting itself to half the displacement path.

[0040] In Figure 11a, in the enlarged detail X of Figure 10, the same details as in Figure 10 have been given the same reference numbers, with reference being made to the previous description.

[0041] In Figure 11b, the enlarged detail X of Figure 10 is in a modified position, with the central joint plane, in its relative position relative to the outer joint part 12<sub>10</sub>, being arbitrarily used as the reference

plane  $E_B$ . With respect hereto, the inner joint part  $14_{10}$  is axially moved towards the right by the displacement path VI, whereas the ball cage  $17_{10}$  is moved towards the right by half the size of the displacement path VC. In this position, an inner edge  $25_{10}$  of the outer joint part  $12_{10}$  stops against the outer face  $21_{10}$  of the ball cage  $17_{10}$ . An outer edge  $27_{10}$  of the ball cage forms a corresponding stop, with the displacement path of the same size extending in the opposite direction. An angle  $\alpha$  at the ball cage  $17_{10}$  is the angle between the central plane of the ball cage and the line of contact with the edge  $25_3$ . The radius of the face  $21_{10}$  at the ball cage has been given the reference symbol RC.

[0042] Figure 12, in a simplified illustration without the cage, shows the outer joint part 12, the inner joint part 14 and the balls 16 which carry the same reference numbers as used in Figure 1. In all three illustrations, the central plane defined by the ball centers is referred to as the central joint plane E, i.e., a new artificial reference plane is not introduced. The tracks 19, 20 are referred to by their track base lines and their track center lines 9, 10 only. For the sake of simplicity, the track edges have also been eliminated. The position of the balls is defined by the points of intersection of the track center lines 9, 10. As a result of the relative displacement  $V_{max}$  between the outer joint part and the inner joint part, the centers of curvature of the track center lines 9, 10 are displaced relative to one another, as a result of which the control angles between the associated track center lines 9, 10 simultaneously change in opposite senses, i.e. the one increases, the other decreases. The minimum distance of the centers of curvature from the central joint plane E is referred to as  $Q_{min}$  and the maximum distance of the centers of curvature from the central joint plane E is referred to as  $Q_{max}$ . The angles between the radii positioned

perpendicularly on the tangents in the points of intersection of the track center lines correspond to the control angles  $\beta_1, \beta_2$  between said track center lines. Each half of said angles between the radii is referred to as  $\beta_{\max}/2, \beta_{\min}/2$ . The axial displacement is to be delimited to such an extent that  $\beta_{\min}/2$  is not less than  $4^\circ$  and that the smallest control angle  $\beta_{\min}$  thus is not less than  $8^\circ$ .

[0043] From the foregoing, it can be seen that there has been brought to the art a new and improved constant velocity joint. While the invention has been described in connection with one or more embodiments, it should be understood that the invention is not limited to those embodiments. Thus, the invention covers all alternatives, modifications, and equivalents as may be included in the spirit and scope of the appended claims.